Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science

6.002 – Electronic Circuits
Fall 2001

Lab Practice & Safety

Introduction

This handout discusses aspects of the experimental lab work that you will perform in 6.002. It begins with a discussion of good lab practice, and ends with a discussion of lab safety. You should pay special attention to the EECS Electrical Safety Notice attached to the end of this handout. As indicated, it must be signed and returned to the EECS Instrument Desk in the Lab in order for you to pick up your lab kit.

Your Lab Notebook

Your lab notebook should become a complete and permanent record of the experiments you perform during the semester. The notebook itself should be a bound hard cover notebook with graph-ruled pages. Since your lab notebook should contain your raw experimental data, you should never copy data into your lab notebook from some other paper. If you do not have your lab notebook with you when you record your data, you should staple the page of raw data into your lab notebook. Copying data into your lab notebook after completing an experiment risks beautifying your lab notebook with copying errors.

Like any lab notebook, your 6.002 lab notebook should contain three distinct sections for each experiment performed:

(1) the design, analysis and predictions you complete before your experimental work;

(2) the data and observations you record during your experimental work;

(3) and the analysis and interpretations you complete after your experimental work.

If your lab notebook is organized in this manner, then anyone including yourself should be able to pick up your lab notebook at a later time and follow your preliminary analysis, reconstruct the experiments you performed, reproduce your raw data, and reach equivalent conclusions.

Since your lab work is only useful if it can be explained to and reproduced by others, your lab notebook must be more than analyses and numbers with no context. The following guidelines should help you produce more consistent lab records with clear distinctions between your expectations, your actual data, and your analysis of the data.

Pre-Lab Work

Pre-lab work is designed to motivate and define your experiments, and thus prepare you for your in-lab work. Pre-lab work should be treated like a small homework, and should be written up in your lab notebook. The questions asked in the 6.002 pre-lab assignments are indicative of the type of questions you should ask when examining a scientific or engineering hypothesis. Your analysis of these questions should motivate and guide the experiments you will perform, and suggest how the experimental results will confirm or refute the hypothesis under examination.

The 6.002 pre-lab assignments will generally analyze and predict the performance of an electronic circuit, and result in predictions for the data you will record during your in-lab work. As you work through the assignments, you should think about how you could experimentally determine whether your analysis is correct. If you do not see how the in-lab work seeks to verify your pre-lab work, then neither effort is of value even if both are correctly performed. Finally, as you work on the pre-lab assignments, you should take the time to neatly draw the circuits you will build during your in-lab work, and to prepare any graphs and tables necessary to organize data recording.

In-Lab Work

The notes you take during your in-lab work are simply a record of what you did and what you observed. A minimal record includes at least the following.

(1) A labeled circuit diagram in your lab notebook adjacent to the recorded data. The diagram should include: voltage and current source amplitudes and frequencies; resistor, capacitor, and inductor values; semiconductor and integrated circuit names; oscilloscope and multimeter connections; and any other comments you think are important to circuit operation such as shielding, component temperature and so on. You should also note or sketch your predictions before you take a measurement.

(2) A record of your specific procedures and measurements. This should include key oscilloscope and multimeter settings, source adjustments made while recording data, small component changes and so on. You should record raw data in your notebook and interpret it later, even if later means only a few minutes later before you move on to the next experiment. For example, if you use the voltage drop across a resistor to measure a current you should record the measured voltages in your lab notebook and convert these measurements to current later. If any data is unexpectedly large or small, or noisy or noise-free, for example, or some adjustment is particularly large or sensitive, you should note this in your lab notebook as part of the data. Finally, included in your notebook should be all comments necessary to recreate your experimental procedure.

    Waveforms sketched directly from the oscilloscope warrant a few additional guidelines. Never make a rough sketch that you will copy into your lab notebook later; each time data is copied from one medium to another, new errors and interpretations creep silently into the data. Rather, neatly sketch the waveform directly into your lab notebook as accurately as possible. Such sketches should be at least as large as the oscilloscope screen, and are most accurate if you let the ruled squares of your notebook graph paper correspond to the ruled graticule on the oscilloscope screen.

(3) Commentary about inaccuracies in your data. Record and plot precisely what you see as accurately as possible; do not record what you expect to see. Related to the accurate recording of data is the issue of precision. You must indicate in your data how precise your readings are. Such an indication can be as simple as an estimate of the noise in the measurement. When sketching oscilloscope data be sure to indicate the trace width and any other relevant features of the waveform.

Post-Lab Work

Post-lab work concerns your interpretation of your results in terms of the analyses and predictions of your pre-lab work. It is the time to discuss not only what the data tells you about the circuit operation but also whether the data answers your questions from the pre-lab, and supports or refutes any hypotheses you have made. Important questions to ask and answer in the notebook include at least the following.

(1) Did the data match the predictions? Why or why not?

(2) What does the data say about the theories used to derive the predictions? Under what conditions do the theories apply and why? Were those conditions met during the in-lab work?

(3) What factors could be generating what appear to be bad data? How might the pre-lab analyses be modified to make more accurate predictions in the future? How could the experiments be modified to obtain more accurate data?

The post-lab work is also the time to combine data from different experiments in order to reach more general conclusions.

Oscilloscope Readings

Make your measurements at the middle of the trace. A widened trace is most often caused by added noise. In this case, the reasonable assumption that the average of the noise is zero leads to the conclusion that the true value of the signal lies at the middle of the trace. This is particularly important when measuring the peak to peak voltage of a periodic signal. Even in the presence of a little noise, measuring from the extremes of the trace can easily add 3% to 5% to the measurement, thereby reducing its precision to less than two digits.

The oscilloscope is an extremely versatile measuring instrument and you should attempt to take advantage of its capabilities. Adjust the voltage scale so that the waveform fills the scope screen and the effects of trace width are minimized. In general, do not hesitate to move the trace around on the screen or expand interesting parts of the waveform in order to get a more accurate view of its detailed behavior.

Breadboarding Practice

Follow the breadboarding practice outlined below to will generally help guarantee that your circuit will work as well as possible.

(1) **Lay the circuit out as neatly as possible.** Having the component locations correspond to the circuit diagram will aid in locating test points. Such a lay out is also easiest to check for wiring errors.

(2) Make all wires and leads as short as possible. Long wires and leads increase stray capacitance and inductance which can be significant in high-frequency circuits.

(3) Take care when inserting and removing integrated circuits to and from the breadboard so as to avoid bending the pins. To remove a DIP, insert a screwdriver or other thin object under the package and pry up gently. It is best to pry a little on alternate sides so the pins are not

bent in any direction. Never pull out an integrated circuit or other circuit element with the power connected.

(4) If your circuit exhibits significant noise, significant distortion, or poor high-frequency or performance, try by-passing the power supplies by placing 0.1-μF capacitors across the positive supplies. Also, place similar capacitors across the power supply terminals of all integrated circuits. Also **make sure all test equipment probes are grounded to the same node of the circuit under test.**

(5) Note that the ground leads of the two oscilloscope probes are connected together inside the oscilloscope. Thus, the ground leads of the two probes *must* be connected to the same node of the circuit under test. Indeed, all the test equipment in the lab is grounded together, so, for example, the signal-generator ground must connect to the same node as the oscilloscope ground.

Safety

Safety is a very important component of good lab practice. Accordingly, please read and follow the attached Electrical Safety Notice provided by the EECS Department. As indicated, it is necessary to sign the last page of the notice and return it to the EECS Instrument Desk in the Lab in order for you to pick up your lab kit.